Producer-Consumer Biomass in Arizona Ponderosa Pine

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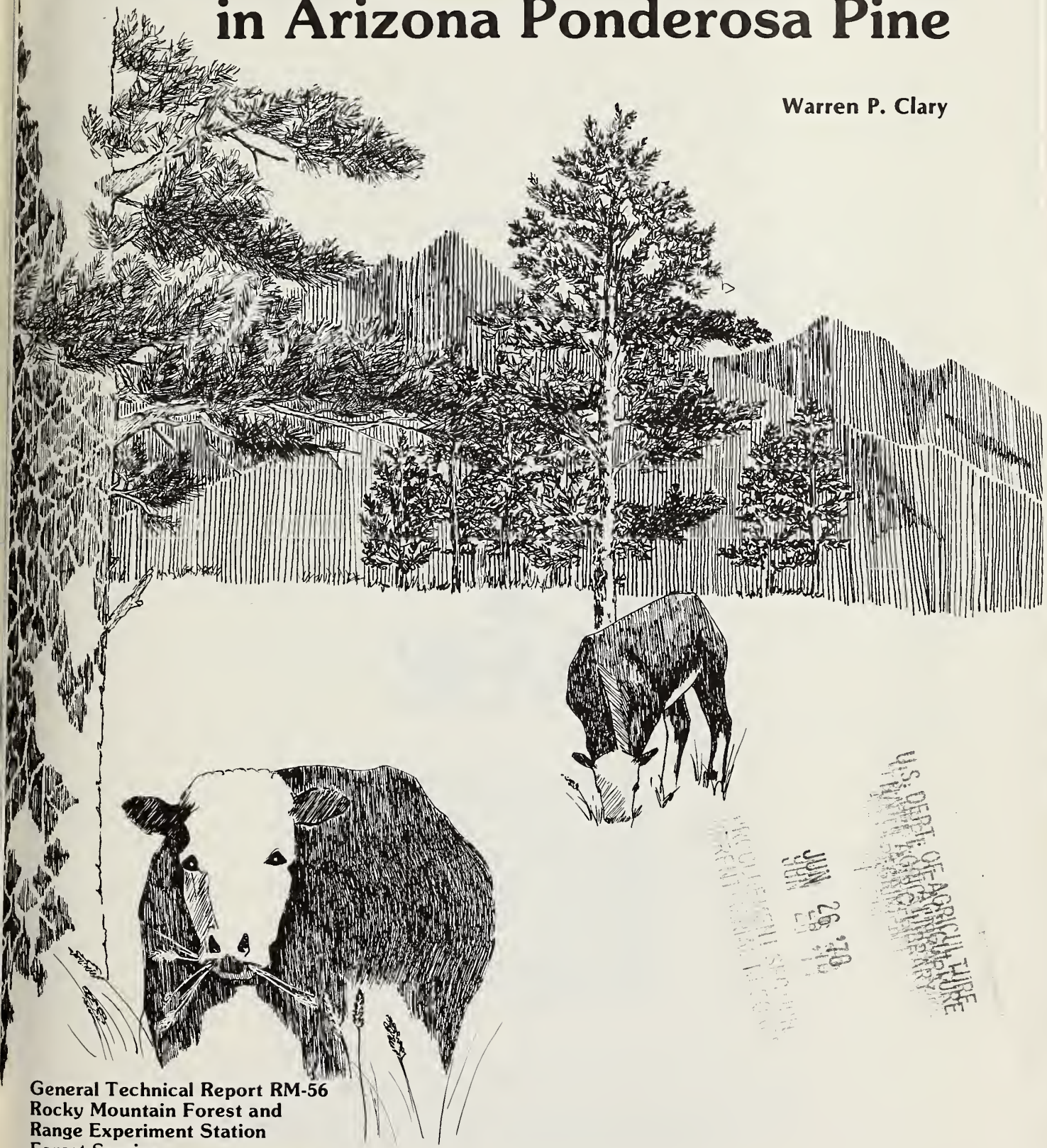

General Technical Report RM-56
Rocky Mountain Forest and
Range Experiment Station
Forest Service
U.S. Department of Agriculture

Abstract

Managed ponderosa pine forests in central Arizona support aboveground biomass of approximately 60,000 to 80,000 kg/ha. Consumer biomass is only about 8-12 kg/ha. Livestock dominate, followed by elk, deer, insects, and small mammals. Forest openings have much less green foliage than the forests, but support three to five times the herbivore biomass per hectare because of the predominance of herbaceous plants.

The Man and the Biosphere (MAB) Program was created by the United Nations Economic and Social Council in 1970 to provide a vehicle for international cooperation on environmental problems. Its principal purpose is to encourage studies of natural systems and human impacts upon them, and to apply the results of such research to improve natural resource management practices. Research reported here involves one of the natural and experimental area reserves designated as biosphere reserves in the United States.

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There are many density levels at which a productive forest can be managed. Each density level will provide a different combination of forest benefits and biological components. One measure of the biological components is the kinds and amounts of biomass represented. As such information is accumulated from a variety of forest conditions, more accurate judgements can be made concerning the impact of vegetation management on the amount of animal life likely to be supported.

Information on biomass pyramids is limited for many vegetation types, although the idea is basic to plant and animal ecology. Consumer data are particularly lacking in forested ecosystems, where mammalian herbivore biomass and activity are relatively less important than in grassland ecosystems.

A comparatively open forest type such as the southwestern ponderosa pine type represents an intermediate ecological position between dense humid forests and the more arid grasslands. Although large herbivores are not as obvious here as in the grasslands, their role is significant. The purpose of this report is to present estimates of producer and consumer biomass for several density levels of managed ponderosa pine forest in central Arizona.

Background

The information was developed primarily from studies on the Beaver Creek watershed (Brown et al. 1974), the Wild Bill Range (Pearson and Jameson 1967), and other areas located on the Coconino Plateau in Arizona. The areas average about 2,300 meters in elevation. The soils, developed on basalt and volcanic cinders, are mostly silty clays and silty clay loams. Precipitation averages 585-635 mm.

Ponderosa pine (*Pinus ponderosa*) is the major tree species. Woodland species such as Gambel oak (*Quercus gambelii*) and alligator juniper (*Juniperus deppeana*) are often present and quaking aspen (*Populus tremuloides*) may be found on the more mesic sites. The herbaceous layer varies in composition from dominance by Arizona fescue (*Festuca arizonica*) and mountain muhly (*Muhlenbergia montana*) to mutton bluegrass (*Poa fendleriana*) and bottlebrush squirreltail (*Sitanion hystrix*). The shrub layer is represented by Gambel oak sprouts and an occasional buckbrush ceanothus (*Ceanothus fendleri*) or rabbitbrush (*Chrysothamnus* spp.). Other shrub species are present on steep rocky hill sides and along stream courses.

The results reported here are part of a cooperative effort which began in the late 1950's. Studies of big game use conducted by the Research Division of the Arizona Game and Fish Department in cooperation with the Rocky Mountain Forest and Range Experiment Station have spanned nearly 20 years. In 1972 the wildlife evaluation effort was expanded to include a broad spectrum of forest wildlife. Briefly, the Arizona Game and Fish Department studied big game habitat use and deer diets; small game inventories and rodent population studies were conducted by the University of Arizona; Northern Arizona University studied bird populations and foliage use, and the Museum of Northern Arizona was responsible for study of insect biomass. The Wildlife Habitat Research Work Unit (USDA Forest Service) in Tempe, Ariz., was responsible for study of: Abert squirrel nesting requirements; quality of mule deer diets; and carnivore food habits and habitat use. The Beaver Creek Multiple Use Research Work Unit (USDA Forest Service) Flagstaff, Ariz., provided coordination and financial support for much of this work.

These studies supplied information on biological components of forest stands being grazed and subject to periodic timber harvest.

Procedures

Specific biomass estimates were made for three levels of ponderosa pine basal area: 23 m^2/ha(100 ft^2/ac); 14 m^2/ha(60 ft^2/ac); and 0 m^2/ha. It is assumed that the starting point was a forest with 23 or more square meters of ponderosa pine basal area plus associated tree species, and that this forest would be brought under uneven-aged management at the prescribed levels. Initially the stands would have about 15% of associated species—principally Gambel oak—in addition to the ponderosa pine. These trees would be largely retained when the pine basal area was reduced to 23 and 14 m^2/ha. All trees would be removed during the creation of forest openings. Sprouting of Gambel oak would be expected to occur.

Consumer biomass calculations assumed uniform distribution of sex and age classes. There was assumed to be no upper restrictions on the hectarage of basal area levels of 14 or 23 m^2/ha for application of these estimates, but the hectarage of 0 basal area would have to be small enough so that deer and elk would utilize the entire opening (perhaps up to 16 ha). The livestock density and residual herbage biomass was based on 40% use of the forage on good condition range.

Information sources used to estimate biomass are shown in tables 1 and 2. Only aboveground living biomass near the end of the growing season was calculated. Two trophic levels are presented—producers and consumers. No attempt was made to separate primary and secondary consumers or estimate the biomass of decomposers.

Results

Forest

Although the aboveground biomass may exceed 80,000 kg/ha, most of it is the woody component of trees (table 3). The foliage component (woody plant foliage plus herbaceous plants) makes up only 6% of the total.

The producer biomass supports a comparatively small amount of consumer biomass (fig. 1). The consumer biomass is only 8-12 kg/ha or 0.01% to 0.02% of the total. Domestic herbivores, principally cattle, make up 85% of consumer biomass. The remainder is contributed by a variety of native species (table 3).

Table 1.—Sources of producer biomass estimates

Woody plants	
Ponderosa pine	Computer-based simulations from Larson (1975)
Gambel oak	Field inventory data for bolewood biomass adjusted to total biomass based on Whittaker and Woodwell (1969)
Shrubs (including Gambel oak sprouts)	Field inventory data for current leaf and twig growth adjusted to total biomass based on Whittaker and Woodwell (1969) and Brown (1976).
Herbaceous plants	Preliminary prediction equation developed from data collected on the study areas: Herbage yield = 143.5 + [0.95 X Oct.-Aug. precip. (mm) + 22.0 X depth to clay or silty clay (cm)] [$e^{-.126 \times \text{Tree Basal Area } (m^2/ha)}$]

Table 2.—Sources of consumer biomass estimates[1]

Domestic	
Cattle	Carrying capacities indicated on the Wild Bill Range (Clary, Kruse, and Larson 1975) and on good condition ranges in the Southwestern Region, U. S. Forest Service (Clary 1975).
Native	
Elk	Animal-days from pellet group counts (Neff 1972, Kruse 1972, Clary and Larson 1971, and Neff, personal communication). Densities in forest openings adjusted according to Reynolds 1962, 1966. Live weight per animal from Murie (1951) and Quimby and Johnson (1951).
Deer	Animal-days from pellet group counts (Neff 1972, Kruse 1972, and Neff, personal communication). Densities in forest openings adjusted according to Reynolds 1962, 1966. Live weight per animal adjusted from McCulloch (1962).
Tree squirrels	Density estimates and live weights from David Patton (personal communication) and Patton, Ratcliff, and Rogers (1976).
Rabbits	Density estimates from pellet counts (Costa, Ffolliott, and Patton 1976) and live weights from Peter Ffolliott (personal communication).
Ground-dwelling rodents	Grid system live trapping for biomass of most species, and mound counts for density of gophers (Goodwin 1975). Biomass for treeless areas adjusted from Terry Hudgins (personal communication).
Birds	Breeding bird densities by spot-map method and live weights from Szaro (1976). Age-class distribution from Weins and Innis (1974).
Insects	Direct sampling of insect biomass (dry weight) per unit weight of foliage (Ronald Young, personal communication)

[1] *Live weights of vertebrates multiplied times 0.3 to give dry weight (Davis and Golley 1965).*

From one-half to two-thirds of the native consumer biomass is contributed by the large mammalian herbivores—elk and deer. Elk biomass is higher than deer biomass. Most of the remainder is made up of insects and small mammalian herbivores. Within the small-mammal group, ground-dwelling rodents predominate over tree squirrels. Rabbits generally have very low populations in southwestern ponderosa pine forests.

As the forest density is reduced, tree foliage and total biomass are reduced, while the biomass of herbaceous and shrubby plants increases. A parallel response in animal life occurs with ground-feeding

consumers tending to increase while those species most directly dependent upon the trees tend to decrease as forest density is reduced.

Examination of the consumer distribution suggests that a majority of the wildlife biomass and nearly all livestock biomass are supported by herbaceous plants, which contribute less than one percent of the total plant biomass. Gambel oak foliage when present provides most of the woody plant contribution to consumer nutrition. Oak leaves are a significant component of the deer diet (Neff 1974) and oak leaves support a higher insect biomass per unit of foliage than does ponderosa pine (Ronald Young, personal communication). Ponderosa pine appears to provide the most direct benefit to tree squirrels and certain bird and insect species.

The biomass values given represent late-growing season situations. Live biomass during mid-winter is lower; nearly all of the herbage, all of the deciduous tree foliage, one-third of the coniferous tree foliage, and a great majority of the consumer biomass are absent at this time. The large herbivores, many birds, and some of the carnivores migrate to warmer winter habitats, leaving a much reduced consumer biomass.

Forest Openings

Although the total foliage per hectare in forest openings is much less than that of the forest (table 3),

Table 3.—Producer-consumer biomass estimates (kg/ha dry weight)

	Ponderosa pine basal area		
	23m²/ha	14m²/ha	0m²/ha
Plant			
Woody plant			
Foliage	4,939	3,482	81
Other	76,715	54,111	324
Total	81,654	57,593	405
Herbaceous plant			
Total	117	184	645
Plant total	81,771	57,777	1,050
Animal			
Domestic			
Cattle	6.7	10.1	31.8
Native			
Elk and deer	.6	1.0	1.8[1]
Ground rodents and rabbits	.1	.2	.3
Tree squirrels	.1	<.1	—
Birds	.1	.1	<.1
Insects	.4	.3	<.1
Animal total	8.0	11.7	33.9

[1]*Biomass of these larger animals is not supported on a continuous basis because of their movements in and out of openings. The biomass value given is proportionate to the amount of use received.*

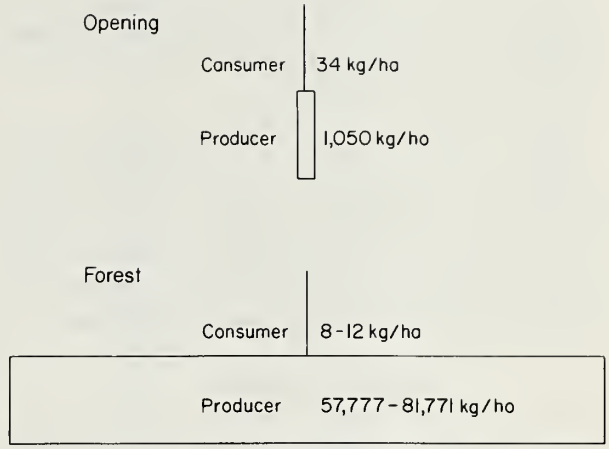

Figure 1.—Simplified biomass pyramids for ponderosa pine forests and forest openings.

it is able to support approximately three times the consumer biomass because of the high proportion of herbaceous foliage. The difference in consumer biomass between the forest and the openings is primarily a reflection of the difference in carrying capacity for livestock.

Ground-dwelling wildlife species also tend to maintain higher biomasses in openings where the productivity of herbaceous vegetation is higher, particularly when cover is present. However, considerable variation can be expected in the densities of both small and large herbivores because of cover requirements. Variations in the size of the opening, topography, presence of woody plants, and the presence of slash and other low cover will result in differences in native herbivore densities. Current information suggests variations of ± 60% to 80%. Animal species shifts also occur as openings become very large if little cover is present (antelope replace elk and deer, for example).

Birds, insects, and tree squirrels are all supported in higher biomasses in the forest than in the openings. Little information is available on carnivore densities. Counts of scats along roadways suggest slightly higher use of openings, where rodent biomasses are higher than in the forest.

Conclusions

Studies in Arizona ponderosa pine forests have shown that a small fraction of the biomass (0.01% to 0.02%) is made up of consumers. Livestock biomasses are supported at rates of about one-fifth to one-third those in forest openings; differences in wildlife biomasses are smaller. The forest appears to provide

more specialized habitats and supports a greater variety of wildlife than do the openings. Tree squirrels, many species of birds, and most of the insects studied require the forest environment.

Large mammalian grazers, native and domestic, dominate the consumer biomass in both the forest and forest openings. Thus, much of the secondary production is channeled into meat supplies easily harvested by man. Forest-adapted birds and tree squirrels, which add greatly to man's enjoyment of the forest, make up little of the consumer biomass.

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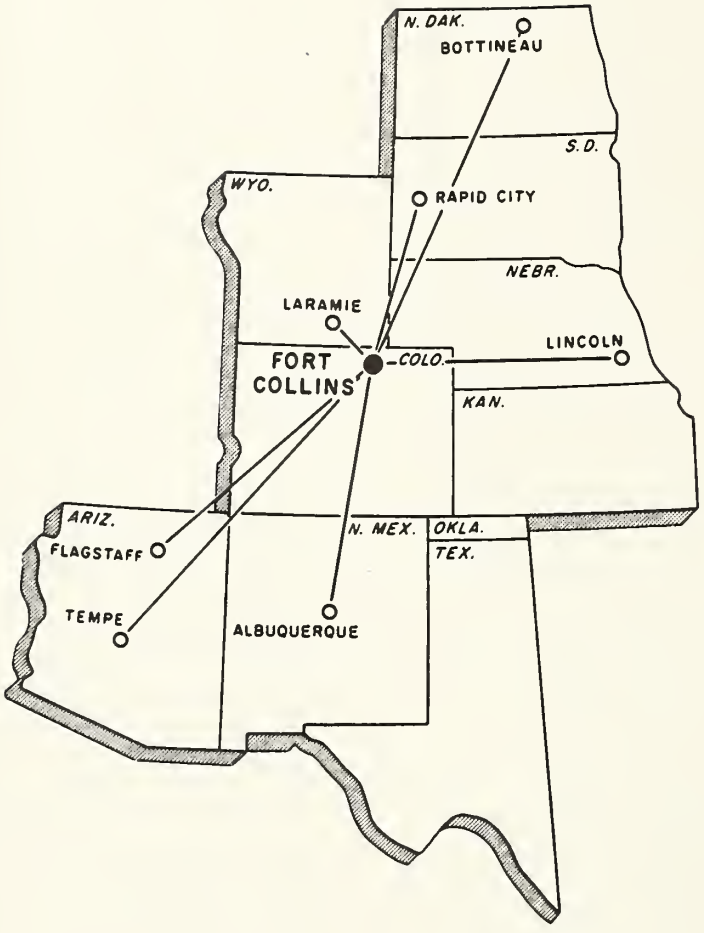
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